

CLAIMS:

- 1 1. A method of diagnosing pathologic heart conditions comprising:
2 parsing a time series of heart sounds into a sequence of individual heart cycles;
3 determining the systolic interval of the heart cycles;
4 identifying a subinterval for each systolic interval of the heart cycles;
5 filtering the time series of heart sounds using a time-frequency transformation;
6 identifying anomalously high wavelet coefficients using a constant false alarm rate
7 (CFAR) detector;
8 assembling the series of anomalously high detections into a matrix;
9 convolving the matrix with an averaging vector, said vector's length derived from the
10 expected time spread of a click occurrence, the convolution yielding detection statistics
11 across heart cycles and time intervals consistent with an observed spread of click occurrence
12 times;
13 calculating a click score as the maximum element of a vector formed by the median
14 wavelet coefficient amplitude across heart cycles squared at each time sample multiplied
15 element-wise by a vector formed by the sum across heart cycles of the number of detections
16 at each time sample; and
17 comparing the click score to a threshold level in order to distinguish between a normal
18 heart and a pathologic heart.

- 1 2. The method of claim 1 further comprising ranking the click score relative to other click
2 scores in a database to establish its standing amongst a population of other click scores of
3 known pathologic and non-pathologic hearts.

- 1 3. The method of claim 1 wherein parsing the time series of heart sounds into a sequence of
2 individual heart cycles uses electro-cardiogram (ECG) data to transform a time series of
3 heart sounds into a sequence of individual heart cycles.

- 1 4. The method of claim 1 wherein parsing the time series of heart sounds into a sequence of
2 individual heart cycles uses acoustic heart sounds obtained directly from a patient to
3 transform a time series of heart sounds into a sequence of individual heart cycles.
- 1 5. The method of claim 1 wherein determining the systolic interval of the heart cycles is
2 achieved by identifying pulses on an electro-cardiogram (ECG).
- 1 6. The method of claim 1 wherein determining the systolic interval of the heart cycles is
2 achieved by acoustically locating a first and a second heart sound using a bandpass filter,
3 said bandpass filter applied to the time series of heart sounds.
- 1 7. The method of claim 1 wherein the systolic sub-interval is centered in the systolic
2 interval.
- 1 8. The method of claim 1 wherein the systolic sub-interval is centered in systole and spans
2 half of the systolic interval.
- 1 9. The method of claim 1 wherein filtering the time series of heart sounds using a time-
2 frequency transformation is implemented by a second order coiflet continuous wavelet
3 transform (CWT).
- 1 10. The method of claim 1 wherein filtering the time series of heart sounds using a time-
2 frequency transformation is implemented by a Fourier transform.
- 1 11. A system for diagnosing pathologic heart conditions comprising:
2 means for parsing a time series of heart sounds into a sequence of individual heart cycles;
3 means for determining the systolic interval of the heart cycles;
4 means for identifying a subinterval for each systolic interval of the heart cycles;
5 means for filtering the time series of heart sounds using a time-frequency transformation;
6 means for identifying anomalously high wavelet coefficients using a constant false alarm
7 rate (CFAR) detector;

1 means for assembling the series of anomalously high detections into a matrix;
 2 means for convolving the matrix with an averaging vector, said vector's length derived
 3 from the expected time spread of a click occurrence, the convolution yielding detection
 4 statistics across heart cycles and time intervals consistent with an observed spread of click
 5 occurrence times;
 6 means for calculating a click score as the maximum element of a vector formed by the
 7 median wavelet coefficient amplitude across heart cycles squared at each time sample
 8 multiplied element-wise by a vector formed by the sum across heart cycles of the number of
 9 detections at each time sample;
 10 means for comparing the click score to a threshold level in order to distinguish between a
 11 normal heart and a pathologic heart; and
 12 means for ranking the click score relative to others in a database to establish its standing
 13 amongst a population of other scores of known pathologic and non-pathologic cases.

1 12. The system of claim 11 further comprising means for ranking the click score relative to
 2 other click scores in a database to establish its standing amongst a population of other
 3 click scores of known pathologic and non-pathologic hearts.

1 13. The system of claim 11 wherein the means for parsing the time series of heart sounds into
 2 a sequence of individual heart cycles uses electro-cardiogram (ECG) data to transform a
 3 time series of heart sounds into a sequence of individual heart cycles.

1 14. The system of claim 11 wherein the means for parsing the time series of heart sounds into
 2 a sequence of individual heart cycles uses acoustic heart sounds obtained directly from a
 3 patient to transform a time series of heart sounds into a sequence of individual heart
 4 cycles.

1 15. The system of claim 11 wherein the means for determining the systolic interval of the
 2 heart cycles is achieved by identifying pulses on an electro-cardiogram (ECG).

1 16. The system of claim 11 wherein the means for determining the systolic interval of the
2 heart cycles is achieved by acoustically locating a first and a second heart sound using a
3 bandpass filter, said bandpass filter applied to the time series of heart sounds.

1 17. The system of claim 11 wherein the systolic sub-interval is centered in the systolic
2 interval.

1 18. The system of claim 11 wherein the systolic sub-interval is centered in systole and spans
2 half of the systolic interval.

1 19. The system of claim 11 wherein the means for filtering the time series of heart sounds
2 using a time-frequency transformation is implemented by a second order coiflet
3 continuous wavelet transform (CWT).

1 20. The system of claim 11 wherein the means for filtering the time series of heart sounds
2 using a time-frequency transformation is implemented by a Fourier transform.

1 21. A computer program product for diagnosing pathologic heart conditions, the computer
2 program product comprising:
3 computer program code for parsing a time series of heart sounds into a sequence of
4 individual heart cycles;
5 computer program code for determining the systolic interval of the heart cycles;
6 computer program code for identifying a subinterval for each systolic interval of the heart
7 cycles;
8 computer program code for filtering the time series of heart sounds using a time-
9 frequency transformation;
10 computer program code for identifying anomalously high wavelet coefficients using a
11 constant false alarm rate (CFAR) detector;
12 computer program code for assembling the series of anomalously high detections into a
13 matrix;

1 computer program code for convolving the matrix with an averaging vector, said vector's
2 length derived from the expected time spread of a click occurrence, the convolution yielding
3 detection statistics across heart cycles and time intervals consistent with an observed spread
4 of click occurrence times;

5 computer program code for calculating a click score as the maximum element of a vector
6 formed by the median wavelet coefficient amplitude across heart cycles squared at each time
7 sample multiplied element-wise by a vector formed by the sum across heart cycles of the
8 number of detections at each time sample;

9 computer program code for comparing the click score to a threshold level in order to
10 distinguish between a normal heart and a pathologic heart; and

11 computer program code for ranking the click score relative to others in a database to
12 establish its standing amongst a population of other scores of known pathologic and non-
13 pathologic cases.

1 22. The computer program product of claim 21 further comprising computer program code
2 for ranking the click score relative to other click scores in a database to establish its
3 standing amongst a population of other click scores of known pathologic and non-
4 pathologic hearts.

1 23. The computer program product of claim 21 wherein the computer program code for
2 parsing the time series of heart sounds into a sequence of individual heart cycles uses
3 electro-cardiogram (ECG) data to transform a time series of heart sounds into a sequence
4 of individual heart cycles.

1 24. The computer program product of claim 21 wherein the computer program code for
2 parsing the time series of heart sounds into a sequence of individual heart cycles uses
3 acoustic heart sounds obtained directly from a patient to transform a time series of heart
4 sounds into a sequence of individual heart cycles.

- 1 25. The computer program product of claim 21 wherein the computer program code for
2 determining the systolic interval of the heart cycles is achieved by identifying pulses on
3 an electro-cardiogram (ECG).
- 1 26. The computer program product of claim 21 wherein the computer program code for
2 determining the systolic interval of the heart cycles is achieved by acoustically locating a
3 first and a second heart sound using a bandpass filter, said bandpass filter applied to the
4 time series of heart sounds.
- 1 27. The computer program product of claim 21 wherein the systolic sub-interval is centered
2 in the systolic interval.
- 1 28. The computer program product of claim 21 wherein the systolic sub-interval is centered
2 in systole and spans half of the systolic interval.
- 1 29. The computer program product of claim 21 wherein the computer program code for
2 filtering the time series of heart sounds using a time-frequency transformation is
3 implemented by a second order coiflet continuous wavelet transform (CWT).
- 1 30. The computer program product of claim 21 wherein the computer program code for
2 filtering the time series of heart sounds using a time-frequency transformation is
3 implemented by a Fourier transform.